Project-Based Learning Practices in Computer Science Education

Sally Fincher, Computing Laboratory, University of Kent at Canterbury, Canterbury, Kent, England
Marian Petre, Centre for Informatics Education Research, Open University, Milton Keynes, England

Abstract *- The EPCoS project (Effective Projectwork in Computer Science) is working to map the range of project-based learning practices in UK Higher Education and to generate insights into what characterizes the contexts in which particular techniques are effective.*

In assembling a body of authentic examples, EPCoS aims to provide a resource that enables extrapolation and synthesis of new techniques. To allow educators and researchers to mine this material, EPCoS is systematizing it within a template-based catalogue, augmented with indexing and abstracting devices. Moreover, EPCoS is examining the process by which practices are transferred between institutional contexts, with a view to identifying effective models of the transfer process. Three key elements of transfer are the identification of appropriate practices, the selection of a practice for a purpose, and the integration of a chosen practice into the existing culture.

Structured resources and process models are essential tools for supporting responsiveness in the current climate of continual change: the rapid development of computer technology is demanding new range and flexibility in project work, and EPCoS's mapping of project-based teaching allows practitioners to respond to these changes. This is one context in which educational research into how projects work can generalize to professional practice.

Introduction: Why project work matters

The Computer Science (CS) academic community regards group project work as an essential component of any degree; the discipline's professional societies world-wide emphasize project and group work as preparation for professional practice. Project work is recognized as having many educational and social benefits, in particular providing students with opportunities for active learning.

Yet managing project work is problematic, because Computer Science projects are:

- *expensive*, demanding considerable supervision as well as technical resources;
- *complex*, marrying design, human communication, human-computer interaction, and technology to satisfy objectives ranging from consolidation of technical skills through provoking insight into organizational practice, teamwork and professional issues, to inculcating academic discipline and presentation skills;
- *continually demanding*, set in the context of a rapidly changing technology which affects technical objectives and demands ever-evolving skills in both students and supervisors. In a young and changing discipline, some aspect of project work is questioned in almost every institution.

Most Computer Science departments incorporate project work into their degrees, and many have evolved imaginative and effective ways of managing student projects (and evolved away from unsatisfactory and less cost-effective practices), but most of this educational development is done in isolation. The lessons learned in a particular institution are rarely generalized, and the good practices are rarely disseminated, because differences in constraints and requirements of different departments make it difficult to determine if someone else's good idea is actually a good, practical match for one's own needs. CS educators swap experiences in a variety of ways—at conferences and workshops, via newsgroups and discussion lists—but real, practical transfer requires more than anecdote. The EPCoS [1] project (Effective Projectwork in Computer Science) aims to get beyond anecdote:

- to amass a collection of experiences of project work from a range of institutions;
- to systematize the collection in a way that makes it easier to access and compare experiences their particular characteristics, and in this way to make it easier to transfer practice between institutions;
- to realise techniques for transferring project work practices between institutions, and to execute and evaluate such transfers.

Thus, we aim to provide relevant and *usable* information for CS academics who are interested in changing/improving their current project work practices. This paper discusses work-to-date, focussing on active learning in project work, the "catalogue" of project work experiences, its presentation and implementation, and our models of transfer.

Active learning within project work

The concept of "active learning" has been described and outlined by some of the seminal educationalists of this century - Rousseau, Piaget and Dewey amongst them. It remains the case, however, that these thinkers and writers were principally concerned with the child, and therefore with child-centred education; their interest strayed very little beyond the primary (kindergarten) and secondary (high-school) level and the territory of tertiary (college) education was left largely uncharted by them. Consequently, it is not surprising to read that "… educators' use of the term 'active learning' has relied more on intuitive understanding than a common definition" [2]. However far from the originating impulse the concept of active learning is from the average college student, though, the concept of "project work" is much closer — both to the educational theory and to the practice itself, as delivered and as experienced. One of the

early proponents of "active learning", W. H. Kilpatrick (a graduate student of John Dewey's), wrote a treatise in the *Teachers College Record* in 1918 entitled the *Project Method* (which resulted in 60,000 reprints) [3]. In this article, he described the project method as "a purposeful activity carried to completion in a natural setting". Even today, with practical and practicing educators who have never heard of him, this definition seems to describe their intent. More interestingly, for our purposes, it also seems to match the interests, inclinations and requirements of the professional bodies responsible for accrediting the education of future professionals and the (rather less defined) body known throughout the academic world as "Industry".

For teachers, project work appears to have a dual purpose within the curriculum [4]. First, it is included to provide an opportunity for students to synthesise the knowledge they have gained elsewhere in the course. This is especially true of the "capstone" project, but it is also the case with other, lower-level uses of the method. Second, it is included "because it mirrors the requirements of Industry." Project work has always been conceived (however fuzzily) as a mechanism to enable Active Learning in students. The motives within CS disciplinary community are more openly articulated in such phrases as "requiring the students to situate the problem within a context", "to examine the problem-space as well as the problem", "to provide a real-world situation". These viewpoints seem to embody the aspect of Active Learning theory which situates learning within the "real world" or in a context as close to the "real world" as possible (a strong thread in the literature is that of the societal relevance of learning). This has led to many extensions of academic practice to encompass ever more genuine examples of "real world" practice — the most extreme UK example of which is the "sandwich" year, in which a student studies at a University for two years, spends a year working for an employer, then returns to the University for a final year of study before earning the degree. There are also other, more modified, examples of this which try to simulate the experience of working, and therefore stimulate the involvement, which characterises active learning [5].

However, Active Learning is not only the mechanism (for teachers) whereby students can demonstrate knowledge; it can also be the method (for learners) by which they acquire knowledge. This is a very different thing, and a thing less commonly appreciated by educators. It is noticeable however, that many students enjoy the active learning practices embedded in project based learning. Indeed, a common teachers' lament is that they find project work so engaging that they spend a disproportionate amount of time (in regard to the amount of marks the activity carries) to the detriment of other courses and other modes of study. And yet, of all the modes of learning current in Higher Education, it is this project-based active learning which most closely models professional practice in "Industry".

If Active Learning is both desirable and central to projectwork aims and practices it is nevertheless impossible to require, difficult to engender and problematic to transfer success from one situation to another. We have, in the work of EPCoS, spent considerable time and effort considering such intangible aspects of successful teaching practice (as exemplified by the example of Active Learning and projectwork), ways in which they may be captured and conceptual frameworks in which they might be placed. We describe our axioms, progress and achievements to date in the rest of the paper.

General description of the work of EPCoS

The EPCoS consortium was founded and funded under the UK *Fund for Development of Teaching and Learning* (FDTL). The aims of FDTL are:

- to stimulate developments in teaching and learning
- to secure the widest possible involvement of institutions in the take-up and implementation of good teaching and learning practice.

Within these over-arching criteria EPCoS concentrates on a mode of delivery within a curriculum. As a ten-partner consortium, we already had access to a range of examples and experience in this area. However, there was no scale against which we could judge how standard any given experience was. Consequently our first phase of activity was devoted to collecting detailed information on where and how projectwork was included in CS courses (via the Template and made available to the wider community through the Catalogue and Atlas). Our second phase was to extract best practices from this corpus and prepare them for transfer to other institutional contexts. Our third phase will be to undertake such transfers with a view to identifying effective models of that process.

To maximise the efficiency and effectiveness of our work, each partner in the consortium adopted a specific aspect on which to concentrate, addressing eight axes of practice within projectwork: technical outcomes, allocation, management models, assessment issues, negotiated learning contracts, large team projects, integrating project and curriculum, and non-technical or 'professional' issues. Each of the consortium partners is examining one axis through analysis of the catalogue material, and our products (especially the Atlas) have been organized to reflect the eight axes.

Within our investigation of these aspects the question is not whether CS educators are consciously articulating a body of educational theory in their teaching, but rather whether what they are doing *works* — for whatever reason. We believe that we can demonstrate a reasonable theoretical model which encompasses the practice (virtually universal within the CS curriculum) of project work, but that alone will not encourage any educator to adopt (or drop) it. What gives the practice of project work its currency is the demonstrable results — and these may be ascribed to many causes [6].

Our aim encompasses both the tangible and intangible; to make available sufficiently detailed descriptions of practice so that projectwork experience within the CS community is

captured and to articulate the underlying approaches which will allow practices to be transferred with success.

EPCoS Products you can touch: The Template, the Archive, the Atlas & the Catalogue

The first phase of work (to April 1998) has been to solicit, collect and collate project work experiences from universities throughout the UK (aiming for input from all of them). The project's funding necessitates a national focus, but the collection also includes experiences of international colleagues. Because it is based on systematically-collected data organized in accordance with a standard "Template", the collection provides comparability of practice by its configuration. The material captured by the template includes both quantitative and qualitative descriptions of existing practices. This template-based data is collated in three forms:

- i) an "Archive", the complete Web database of projectwork instances, with links to any supplementary material, either electronic or paper-based;
- ii) an "Atlas", an abstraction of the data archive in tabular form which allows easy identification of patterns of practice; and
- iii) a "Catalogue", a representative collection of projectwork practices produced in comparable form and set in a conceptual framework.

The aim is to provide efficient, flexible access to the data we collate, making it is straightforward to pick out and compare particular aspects of many examples.

The Template

The template is derived from an analysis of how educators describe their practices to each other, and what information they use to characterize their project work. It covers aspects of scale, context, learning objectives, project management structure, assessment basis and mechanisms, history and evolution of practices, parameters pertaining to group projects, and self-assessment of the experience with the particular 'instance' of project work.

The template, a questionnaire of about 100 open, short-answer questions, elicits quantitative responses (e.g., number of students per project, duration of project in hours, expected staff contact hours, failure rates) and qualitative responses giving information about the 'published' character of the project work (e.g., learning objectives, pre-requisites, assessment criteria), the teaching and institutional context (e.g., the motivation for running the project in its current form, whether aspects like teamwork or project management are taught explicitly, whether the emphasis is on the product or the process, whether the project is part of a course accredited by a professional body), the history (e.g., how expected technical outcomes have changed over time), and reflection on experience (e.g., whether there are any groups of students for whom the set-up works particularly well or poorly, perception of success).

The Archive

The Archive is simply a Web database of all of the data collected, giving pointers to any supplementary material (e.g., project notes, assessment schemes, instructions to students, course booklets, etc.) provided by the contributing institutions. The Archive is augmented by simple and adaptable (i.e., unassuming) search, select and sort tools, including:

- simple **selection** tools which will abstract material by 'instance' or by template question (across every instance in the database);
- a simple keyword **search** mechanism, so that answers to template questions can be extracted by topic or theme;
- a **profiling** tool: enquirers can fill in an on-line form which allows them to request a shortlist of instances which display certain characteristics.

The Atlas

The Atlas is an encapsulation of the template data in tabular form. Its first release was as a 60cm by 85cm poster showing 54 instances. The instances (columns) are grouped as individual and group projects, and sub-grouped in terms of year of presentation. The abstracted questions (rows) are grouped in themes or aspects (e.g., scale, context, supervision, assessment). This form assists familiarity with the 'shape' of the data and provides at-a-glance comparability between practices. For example, one can scan the 7 lines of the 'scale' section and gain an impression of the range of project sizes, durations, staff resource, and student numbers. Or one might ask particular questions, like "Who else uses log books?", and count 'tick marks' across the relevant row.

The short-answer template questions are abstracted into numeric or yes/no questions, with answers reflected in the table as numbers or ranges, or as symbols for yes/no/where appropriate/not applicable/not specified. Hence, some template questions transfer directly to the Atlas (e.g., number of students per project), whereas others require simplification or translation. For example, the template question requesting a list of deliverables is translated into a list of typical deliverables (based on the collected data), with 'tick marks' for those used in the given instance. The lists of learning objectives (covered in the template in several questions) have been analysed for components and are reflected in the Atlas under specific yes/no questions such as "Do you address any professional issues?" and "Are there non-technical learning objectives?"

While it is a useful overview tool, this form of data presentation is attended by two cautions. First, any encapsulation involves abstraction (i.e., selection and simplification), and the symbols we employ neither capture nor convey the richness and complexity of the original data. Second, the Atlas is only concerned with the template-based material and does not (indeed, cannot) encompass the diversity of our additional qualitative evidence. Hence we

conceive the Atlas as a preliminary tool, leading into the more complete Archive data.

The Catalogue

The Catalogue contains and extends the Atlas; it draws representative examples from the full data Archive in order to illustrate the range of projectwork practice in CS. The aim of the Catalogue is to bring the instances to life by associating them with project "war stories" which add vividness and provide human perspective — and to situate the material in a conceptual framework to support reflection. Hence, the Catalogue material encompasses in-depth case studies of standard, unusual or innovative practices, illustrated with anecdotes of frequently-occurring situations. This evidential and anecdotal material is supplemented by short, reflective essays. The Catalogue facilitates access by cross-referencing the Atlas data (where practicable and appropriate) and hence the raw Archive data.

Uses

In assembling a body of authentic examples, EPCoS aims to provide a resource that enables extrapolation and synthesis of new techniques. We hope to present enough contextual detail to enable the CS academic to recognise and "know" the instances presented and thus engage with the material and draw insights from it — and simple, effective access to make exploration and comparison feasible. The resources are designed to be readily accessible to CS educators, who may use them to generate generalizations, to identify emergent patterns, to understand their own practice (or that of a given institution) in the context of the practice of the sector, to identify interesting differences in practice, to seek new perspectives and hence to 'get out of the box' of existing thinking.

The particular advantage of presenting techniques in context lies in the assessment of 'fitness for purpose'. Good pedagogy is not just good ideas, but good ideas that fit within educational contexts, with their unavoidable constraints. The catalogue can assist academics in understanding the cultural and organizational factors that make an idea effective in practice, e.g., figuring out for a given technique what characterizes the instances in which it succeeds, and how those are distinguished from the instances in which it fails (e.g., a technique that works well with final-year students may fail with first-year students, or a change in assessment method may make a technique less relevant).

The availability of such a large amount of data is unusual in UK CS education. The material has been collected primarily to assist pedagogic development, and the presentation is designed to assist and support the practitioner. However, it would be simple-minded to overlook the suitability of this body of material for mining by other educational researchers.

Why use technology?

People exchange "war stories" routinely and without much effect; technology makes it possible to make use of that experience in a systematic, intelligent way. The uses described above rely on the presentation of a large corpus of examples in a systematic and comparable form; technology makes it easier to bring such a catalogue to life, to 'make sense' and 'make meaning' from an otherwise apparently disparate set of anecdotes. Fast and flexible search, select, and sort tools make it feasible to compare a large number of factors for a large number of examples, in order to try to analyse what characterizes 'fitness for purpose'. The template gives us the form for comparison; technology gives us the tools to make comparison — and juxtaposition — relatively easy and quick, in a domain in which practitioners are pressed for time and attention.

We need to make our data available before it can be used in any way at all. The World-Wide Web (WWW) is an attractive vehicle: cheap, robust (enough), widely available, and with a familiar interface. Simple WWW tools are relatively simple to construct, and simple tools can be enough, as long as they support a clearly defined need. Acknowledging that we cannot anticipate all uses that might be made of the Catalogue, we have erred toward building simple and adaptable (i.e., unassuming) tools, rather than providing a more sophisticated, and therefore constraining, toolset.

An unexpected feature of the data collection has been the quantity of "supplementary material" which institutions have provided. Where possible (respecting requested anonymity), we have annotated the database to indicate this supplementary material and, where possible, included it. However, a more thorough (and beneficial) use of the technology would be to extend the database to a genuinely distributed resource, with each contributing institution annotating its entry with locally-held materials. In this way, the unifying mechanism of the categorisation would be preserved, and the utility of the data greatly enhanced. (Although this would also bring the attendant problems of coping with an evolving distributed resource.)

EPCoS Products you can't touch: Models of Transfer & Explication of Context

Models of Transfer

Our large-scale data collection is part of a broader effort to encourage productive discourse about project work within the CS academic community. The consortium engages in discussion (and the consequent sharing of information) via electronic media, and it holds face-to-face workshops to encourage mutual dissemination of information about project work within Computer Science. Hence, we encourage the exchange of anecdotal evidence which adds vividness and provides perspective on the evidentially-based information collected using the templates. We also seek insight about

subtle factors that affect success in applying practices, in order to develop better methods for transfer. To this end, as well as working on products in the first phases, the EPCoS consortium has also been working to identify and characterise the processes which lead to an effective use of the material we collect.

It appears that transfer of practice between institutions is rare. When such activity does occur, it is almost always based on chance factors such as personality and opportunity. The project is trying to make it easier to adopt practices from elsewhere, not just by making it easier to find out what other institutions are doing that may be of interest, but also by examining how transfer can be made to happen. The consortium is examining various models of transfer both analytically and practically. Each partner is creating a "transfer product": a package of material that embodies effective practice and that has been generalized and documented to assist take-up by another institution. Each partner will subsequently adopt some practice from another institution and will evaluate the experience of transfer.

Three key elements which enable transfer of practice from one institutional context to another are the *identification* of appropriate practices, the *selection* of a practice for a purpose, and the *integration* of a chosen practice into the existing culture. Within EPCoS our principle categorisation involves three constructs: practices, contexts, and practitioners:

- Practices are created by practitioners and situated within contexts.
- Contexts contain practices and impose constraints.
- Practitioners are the creators of practice.

Identification occurs at the practice level — identification both of a need to change and identification of what might appropriately fulfill the need; *selection* of practice is context-dependent, in most cases there must be a similarity between the originating and receiving contexts to make selection viable. *Integration* is achieved only by the activities of practitioners.

Whilst pedagogic endeavour is rarely stable, this is perhaps especially the case within CS, where curricula are frequently adapted to new technological developments. In terms of project work, such changes affect technical objectives and demand ever-evolving skills in both students and supervisors. As well as these disciplinary changes, changes may also be instigated by the requirements of institutional-level Quality Assurance or Quality Enhancement procedures. However, practitioners also make changes based on practices observed or gathered from elsewhere, located within other institutions and contexts. It would seem that adopting work from this pool of practice would be relatively easy and cost-effective. However, from observational and anecdotal enquiry, we believe that there are few ways in which practice is transferred from one context and integrated into another. In order to share concepts, we have developed a series of metaphoric models which describe and delineate this process of transfer and which are easy to comprehend and discuss. (Of course, like all metaphors, they are not precise, and will break down when probed. Nevertheless, we have found them useful.)

We have identified three main ways in which transfer "naturally occurs": charismatic embedding, piecemeal accretion, and coveting.

Charismatic embedding is a process, which happens when individuals move between institutions and take practice with them. The practice may be of their own invention, or it may be something that they have become accustomed to, and so introduce it in their new setting. The key factor is that the impetus is from a single individual. The success of this sort of transfer (and especially the longevity of the practice in its new setting) would seem to depend not so much on the quality of the element being transferred as the personality and status of the individual who imports it [7]. It is unclear, whether the longevity of the practice in its originating setting is also a consequence of personality, or a measure of the quality of the practice itself.

The second method we have termed **piecemeal accretion**. This is a magpie approach that is characterised by individuals taking fragments of practice from elsewhere and bolting them into their own, local framework. The distinction between charismatic embedding and piecemeal accretion is in the granularity and the scale of the transfer. The former is liable to involve larger and more coherent pieces of practice used on a larger scale (for example structures of courses) which are visible at a departmental level; the latter will more likely be a small piece of practice which can be incorporated by one person into his or her own teaching, without involving any changes which would require departmental (or other QA) approval. An example of this would be the use of "asking anonymous questions" mechanisms [8].

The third naturally-occurring model is that of **coveting**. Coveting is exemplified by individuals who have developed something for their own purposes [9] which they are subsequently convinced to export to another context. The characteristic of this type of transfer is that the impetus comes not from the originator but from the recipient. The originators in no way set out to make an exportable product and do not set themselves up to offer these to a wider market. Nevertheless, their practice or product is discovered and solicited by others (accretors or embedders). At this point the originator becomes involved in adjusting the product to the needs of the new environment. The receiver not only locates but also creates the demand for the product; indeed, in saying, "I want one like yours" the recipient creates the recognition that the piece of practice is a *product* at all.

Within all these models, it is notable that the three key elements of transfer (identification, selection and integration) are not separated. They are embodied within an individual's intimate knowledge of the local situation. Any problems of constraints in the local context (selection) or mis-matches in the suitability of the piece of practice (integration) are subsumed in "knowing what will work", and there is no need for them to be examined explicitly

First is the metaphor of **surgeon**. In this model the surgeon deals with a donor (which might possess any piece of appropriate practice in any institutional context) and a recipient. The recipient is responsible for the identification of the need, the surgeon for the identification and selection of practice from a donor. The surgeon makes every effort to ensure successful integration by matching the contexts and constraints of both parties. The donor provides the essential element of practice, but plays no role in the exchange. (The surgeon must try not to kill either patient.). A modified version of this metaphor is that of **honest broker** where a middle-man acts between two parties. The recipient identifies the need, the broker identifies and makes a selection (or series of selections) but a broker offers no guarantees, and has no further role in the transfer. Integration is therefore the responsibility of the recipient and donor jointly.

Second is the metaphor of **vendor,** who stands between **supplier** and **buyer**. Here the responsibilities are shifted. The vendor pre-selects and packages the practice of the supplier (the original context of the practice selected for transfer) before the need (or type of practice) is identified. The packaging is undertaken in such a way as to either make the practice largely context-independent, or to identify explicitly the constraints which it requires (providing a label of ingredients, as it were). The vendor does not examine the constraints of the buyer's context, but expects the buyer to be aware of them and to take account of them in selecting an appropriate product for integration. (The vendor-buyer half of this process can be compared to the existing practice of piecemeal accretion; in the accretion models, it is the accretors who take the practice "as found" or themselves adapt it for their local conditions.) What a vendor has to offer is a **bundle** of material, which may come from one source or many sources, but which is extracted as far as possible from the originating context and does not require the transfer of other practices and materials to make it work.

Explication of Context

Collecting, collating and making available the raw materials—comparable instances of project work practice, and models of transfer—are essential pre-requisite steps. However, to engage in *effective* transfer, the work of EPCoS is to go beyond simple comparison; this involves a close consideration of the contexts in which practices are situated. A bundle is created from a candidate piece of practice, identified by matching focal characteristics to need. However, identification and selection does not guarantee transferability. For successful transfer to take place either the practice must be context-independent, or the original and target contexts must be compatible. These requirements mean that we must be able to describe context in a way that exposes the features which affect transfer.

To adopt a practice from another institution (or context), it is necessary not only to know what it is, but also on what it depends. For example, the assessment methods of a particular example of project work might be inseparable from the specific deliverables required. We call this sort of relationship a **critical dependency**: one piece of practice cannot be taken without the other. Alternatively, a piece of practice may not be completely dependent on another but should (due to institutional or historical circumstance or due to deliberate and specific design) be considered for transfer along with other, associated, aspects. For example, the group allocation methods used might be (in the originating context) tightly connected to the scale of the project, but they could be adopted for a smaller-scale endeavour. We call this sort of relationship a **critical adjacency**: whilst each piece of practice can be taken individually, they were closely related in their originating context and should be viewed together.

The uncovering of these adjacencies and dependencies requires good local knowledge, is time-consuming and sometimes troublesome; this is especially so when instances are "home grown" and aspects have evolved over time and now appear to be interwoven and interdependent. The unpicking and uncovering of these adjacencies and dependencies in the creation of the bundles is one of the major benefits of EPCoS later-phase products. This benefit accrues to EPCoS because of the luxury of our position. Within a normal academic life, whilst there is time and space to notice and comprehend local pedagogic problems, and possibly there is time to search for some better alternative, there is seldom time to search for constraints and eliminate (or recognise and adopt) them. Yet this is the reality of fitness for purpose. (It is our hope and expectation that, in the latter phases of EPCoS we will be able to refine procedures for the identification of constraints so that the work of categorizing context can be made less labour-intensive.)

Thus we can see that consideration of constraints provides a package that encompasses "fitness for purpose", and once such a package is fully identified in this way, it can be transferred. However, the vehicle of transfer and the primary responsibility for integration is always (and only) with practitioners.

Conclusion

It seems clear even in the preliminary use of early drafts of the Atlas and Catalogue by members of the consortium that they are powerful resources for learning about, understanding, and reflecting on project work practice. Technology makes the catalogue more usable, providing tailored access, fast selection and juxtaposition, and the potential for an extensible, updateable, distributed resource.

Our work has been situated solely within the area of Higher Education. However, the level of abstraction of the ideas represented in our models of transfer and our developing methods for identifying constraints in contexts may prove to have a wider applicability. Other (professional and industrial) domains also have needs to transfer "best practices" from one area to another and quite often these transfers are in the areas of project management and project work. One element of the latter phases of EPCoS will be to

see if our models can be extended to use in professional and industrial contexts.

Structured resources and process models are essential tools for supporting responsiveness in the current climate of continual change: the rapid development of computer technology is demanding new range and flexibility in project work, and EPCoS's mapping of project-based teaching allows practitioners to respond to these changes. This is one context in which educational research into how projects work can generalize to professional practice.

References

1 EPCoS is funded over three years (1996-1999) by the Higher Education Funding Council of England (HEFCE) Fund for the Development for Teaching and Learning (FDTL). The members of the consortium are the Computer Science Departments of the Universities of Exeter, Imperial College, Kent, Leeds, Manchester, Southampton, Teesside and York, and the Centre for Informatics Education Research at the Open University (CIER) and the Computer Science Discipline Network (CSDN). Thus, the consortium represents the full spectrum of British universities — large/small, rural/ metropolitan, "old"/"new", integrated/modular, campus-based/distance-education — and takes full advantage of its diversity in expertise and its recognised teaching excellence.

2 Bonwell, Charles C and Eison, James A Active Learning: Creating Excitement in the Classroom *ERIC Digest* ED 340272, 1991. http://www.ed.gov/databases/ERIC_Digests/ed340272.html

3 Page, M Active Learning: Historical and Contemporary Perspectives, unpublished dissertation, University of Massachusetts, 1990

4 Project EPCoS archives: http://www.cs.ukc.ac.uk/national/CSDN/home/EPCOS/EPCOS.html

5 Industrial Software Project Support Network, University of Sheffield, UK: http://www.dcs.shef.ac.uk/~wmlh/FDTL

6 There are institutions where this is achieved by a clear articulation of the underlying theoretical models in the devising and development of courses. Most notable perhaps is Roskilde University in Denmark where the entire curriculum is based around problem-oriented project work. This means that students are required (in groups) to address a problem, and produce a report, from day one of their University careers. There is no question at Roskilde of the project being a demonstration of knowledge; at Roskilde the project is the vehicle for the acquisition of knowledge. An (English language) introduction to the work at Roskilde is Legge, K. Problem-Oriented Group Project Work at Roskilde University: What is it, How is it Performed, and Why? 1997 Available from Roskilde University, PO Box 260, DK-4000, Roskilde. Denmark

7 Lundberg, W. Article to misc.business.facilitators, 13 June 1997

8 Barnes, D. Students Asking Questions: Facilitating Questioning Aids Understanding and Enhances Software Engineering Skills. *ACM SIGCSE Bulletin*, 29(4):38-41, December 1997.

9 Latham, John T Managing Coursework: Wringing the Stone or Cracking the Nut? in Alexander, S & Magee, P. editors. *3rd Annual Conference on the Teaching of Computing: Computing Curriculum Development and Delivery* pp122-131, Centre for Teaching Computing, Dublin City University, August 1995.